Project Proposal

Design and Simulation of Experimental Rocket Testing Stand

Ethiopian Space Science and Technology Institute

Space Engineering Research & Development Directorate

September 2020

Addis Ababa

Ethiopia

1. Introduction

New rocket designs can be tested on the ground under controlled conditions to test some basic parameters before launching it. The test conditions available are usually described as sea level ambient or altitude. Sea level testing is useful for evaluations of start characteristics for a rockets launched from the ground. However, sea level testing does not provide a true simulation of the majority of the operating environment of the rocket. Better simulations are provided by altitude test facilities.

Structural integrity, system operations, and sea level thrust can be measured and verified. However, rockets are primarily intended for operations in very thin or no atmosphere. Systems that work well on the ground may behave very differently in space. [1]

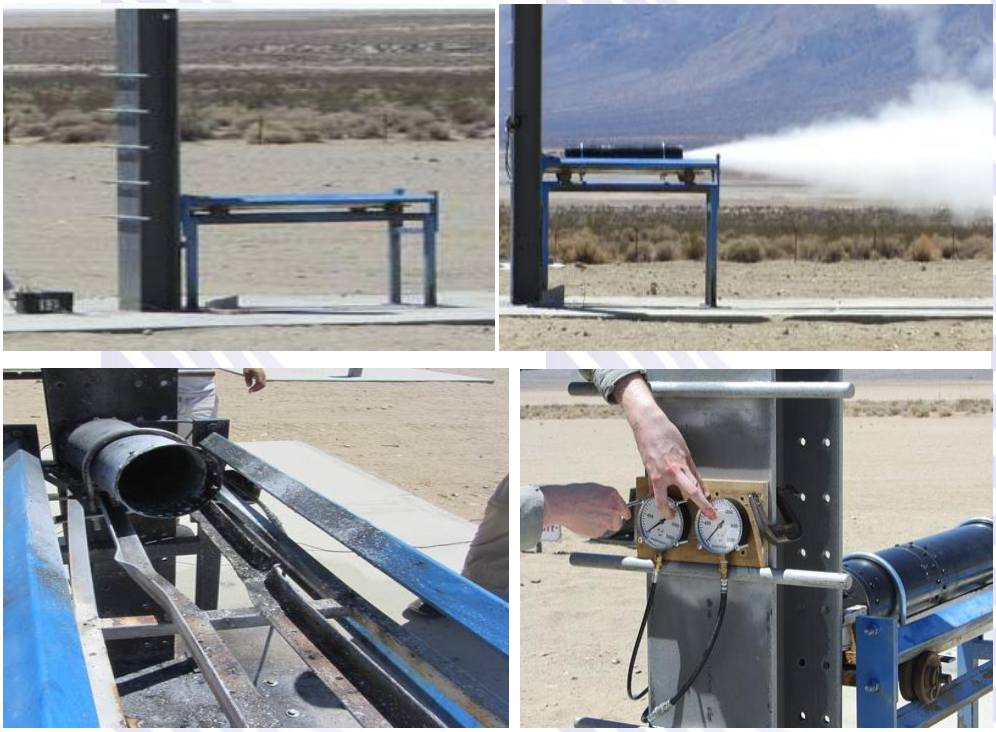


Figure 1 Failed rocket engine testing on the ground

The concept design is modeled from the idea of different testing facilities or stands. We are going to model a horizontally oriented test stand. The bench is prepared to hold the new rocket models with a thrust capacity of 120KN. With this initial parameter the stand will be designed and simulated. This is a middle sized test stand with. Detail transverse and longitudinal beams will incorporate in the design for better strength.

Most of the rocket engine test stand consists of:

- Motor support structure
- Main longitudinal and transverse frames
- Mechanical hard wares and fixtures
- Load cell
- Power supply for the electronics
- Electronics to process the signal
- DAS (Data Aquisition System), in this case it will send the data to a PC. [2]

SAA new 100 KN Thrust Test Stand. In the frame of an exhibition of the Space forum 2001 held by the Swiss Astronautics Association, they presented their newly designed test stand after many trials of testing for this particular thrust value.

With this test stand both liquid engines as well as solid propellant motors with thrust up to 100 KN (10 metric tons) can be tested. The load cells can be exchanged to the respective measuring range. At the moment, a load cell for max. 25 KN is installed. [3]

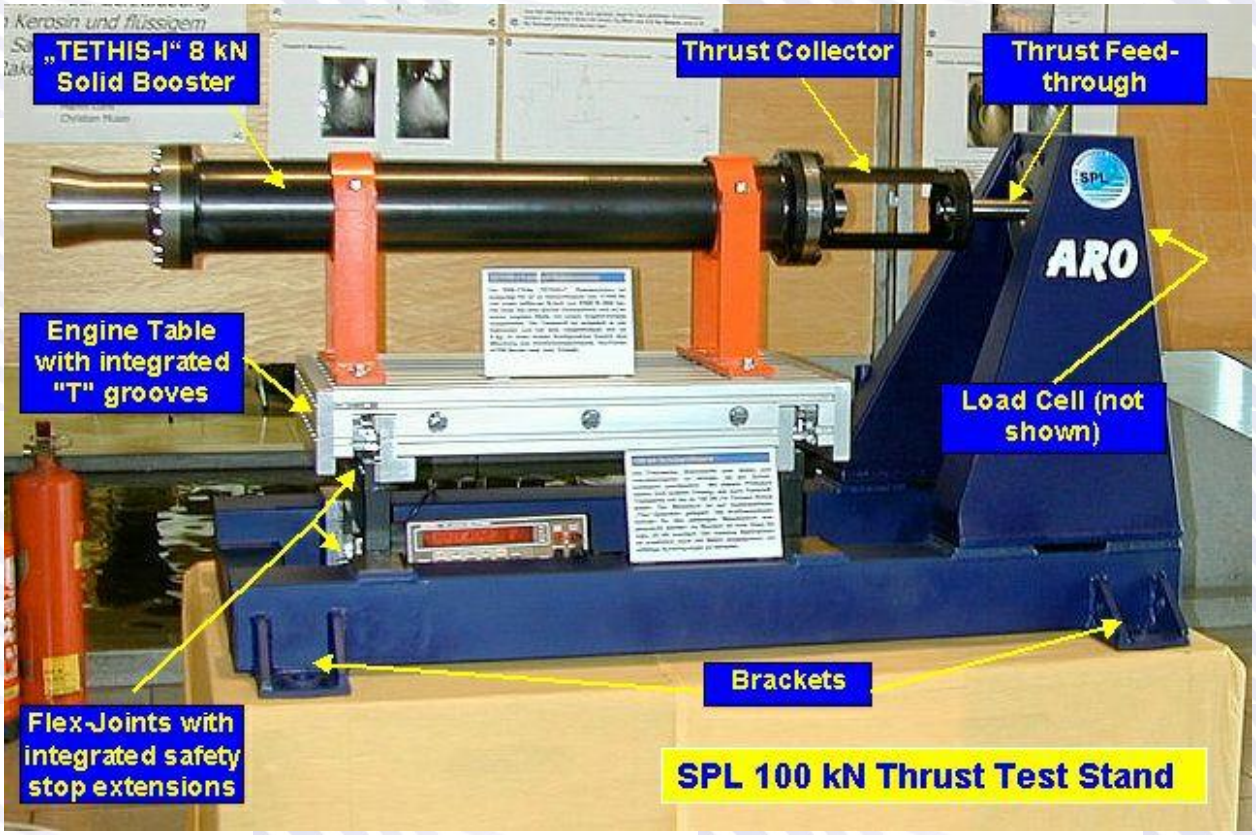


Figure 2 SPL 100 KN thrust test stand

Material

The materials used in the building of the structure are basically beams with different profiles and plates cut into different shapes and sizes. The following table reflects all the parts used in the creation of this structure:

There are different beam profiles and mechanical hard wares as shown below:

Beams	Pates	Mechanical hard wares
Square beam 120X120X5	Rectangular plate	Hexagonal head bolt
Square beam 90X90X5	Circular plate D180X35	Nut
Square beam 90X90X2	Circular rings D180X10X26	Brackets
I-beam 60X60X60		Clamps
NOTE: Beam types are tentative		

Figure Example of beam profiles

The material that will be used in our design is selected a standard steel S235 due to the availability of property data on hand. If any changes is made it will be put on the draft project papers and design files. The material these beams are made of is a structural carbon steel S235. The reasons to select this material are;

- Due to the available data on elastic limit or yield stress (which is the maximum stress that a material can resist while maintaining an elastic behavior)
- The material that will be used should show a plastic behavior (where it cannot return to its initial state).
- If the load is increased on the material the stress should be above that limit.

The selected steel in our structural design is **S235** steel which is helpful in simulation of the 3D design. The following material properties are tabulated for the S235 STEEL.

Parameter	Value
Yield strength	235 N/mm^2
Ultimate strength	350 N/mm^2
Elastic modulus	210,000 N/mm^2
Shear modulus	81,000 N/mm^2
Poisson coefficient	0.3
Thermal dilatation coefficient	$1{,}2.10^{-5}$ $(^oC)^{-1}$
Density	7,850Kg/m^3

The main method of construction of the test stand structure has included the cutting and welding of the different beams together and also bolt holes will be drilled in order to create separable pieces of the structure. For this reason the beams and parts of this structure are mainly bonded together by a combination of welding and bolt.

Simulation and analysis

The model that has been created with the design will be simulated in order to test the structural integrity of the test stand. In this task some of the geometry will be simplified for meshing and computational time reasons.

2. General Objectives

To design and simulate a specific experimental sounding rocket (120KN) testing stand and its systems.

3. Specific Objective

- Design a specific experimental sounding rocket (120KN) testing stand
- Detail designs of the testing stand structures
- 3D modeling of the testing stand
- Mathematical analysis of the structure
- System design using MATLAB SIMULINK
- System design simulation using MATLAB SIMULINK
- Simulate a specific experimental sounding rocket (120KN) test stand

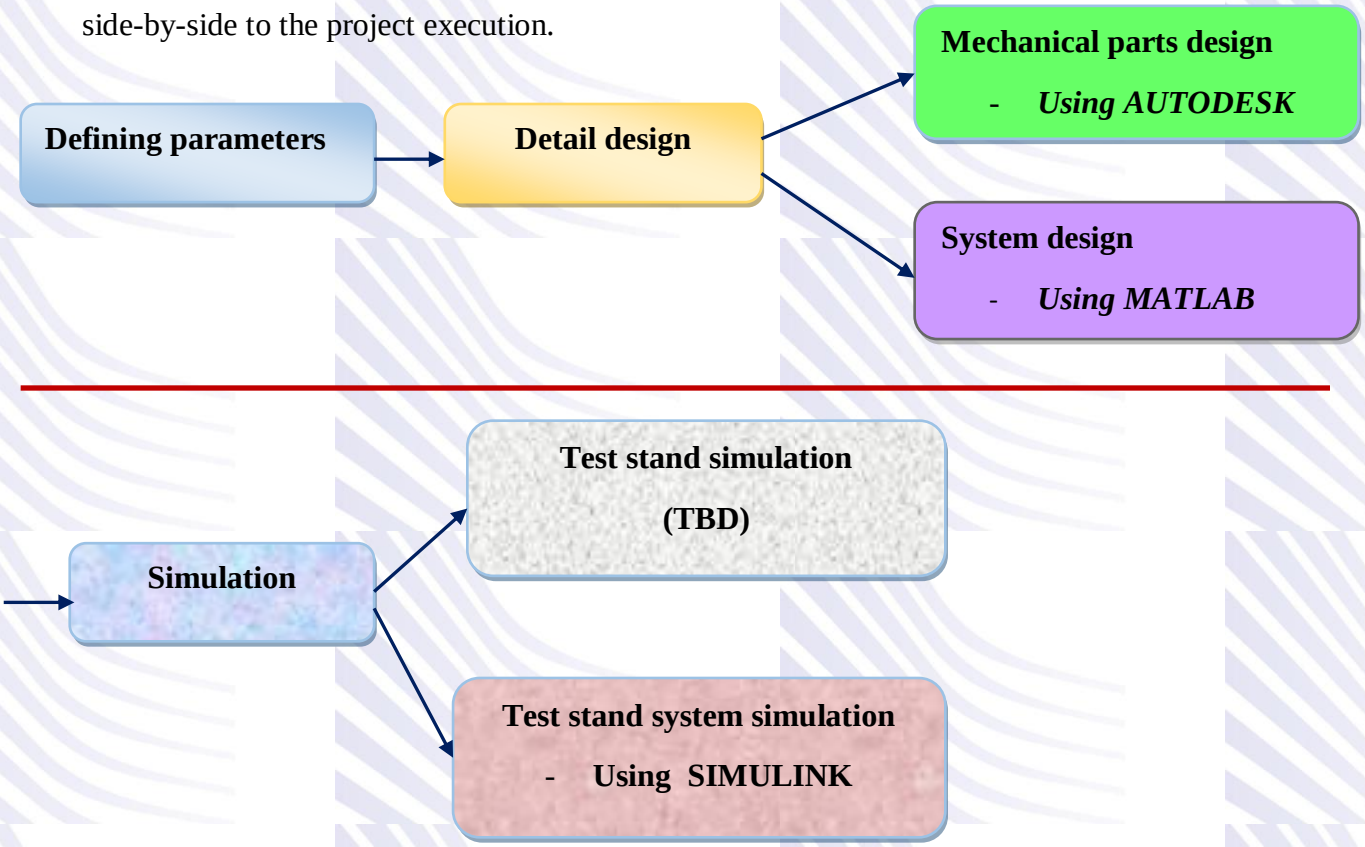
4. Methodology

The methodology to be followed in developing the new project is:

- Defining the basic parameters for the testing stand
- Selection of other new software for rocket engine test stand (if any and accessible)
- Detail designs of the structure (2D) with basic dimensions
- Analyzing the effect of 120KN thrust on the structure mathematically
- 3D modeling of the test stand
- Test stand system design using MATLAB SIMULINK
- Simulation of the complete testing stand

5. The Project Execution Methodology

All the project design and simulation phases will be completed at ESSTI some software trainings may required to make the project more effective. We will identify the type of software for our task side-by-side to the project execution.



6. Budget analysis and personnel

The costs for this research project mainly consist of the cost of the engineering and it doesn't include the cost of the materials since the project objective is to design and simulate an ESSTI model rocket testing stand. The engineering cost comprises the total costs needed to develop the design, build the 3D model of test stand and perform the required simulation works. The costs for the training and possible out-resourcing different simulation tasks as a joint project tasks with different universities is optional.

6.1 Engineering Cost

S/N	Equipment	Price	Remark
1	*Development of the design*		
	▪ *Detail designs* ▪ *3D modeling* ▪ *System design* ▪ *System design simulation*	*not required*	*To be finalized by ESSTI capacity no need to out resource it*
2	*Test stand simulation*	*not required (Optional)*	*To be finalized by ESSTI capacity no need to out resource it*
3	*Training on different software*	*27,000.00*	For simulation
Total Engineering Cost		***27,000.00 Br***	

6.2 Personnel Cost/ Perdiem

S/N	Personnel involved	Qualification	Responsibility	Total No.	Working days	Cost /day	Total Cost
1	Technical Assistant	BSc Graduate	Simulation of designs	1	2	700.00	1400.00
2	Professional	MSc and Above	designing, assisting and Supervising of the design simulation works	2	2	800.00	3200.00
Total							**4600.00 Br**

6.3 Transportation/ Car Rental Cost

S. N	Types of expense	No of Days	Unit price	Total cost
1	Car rent for Transportation	2	1,500.00	3000.00
Total				**3000.00**

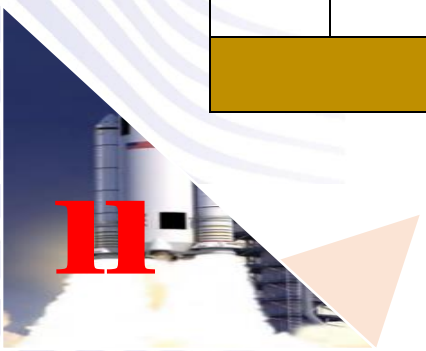
Total Budget Required
Engineering Cost + **Personnel Cost** + Transportation
27,000.00 + 4600.00 + 3000.00
34,600.00 Br

7 Timeline and Milestones for the Entire Project

The overall activity time plan of the research project is presented as follow: -

S/N	Main Research Activities	Duration											
		September	October	November	December	January	February	March	April	May	June	July	August
1	Defining the basic parameters of the rocket engine test stand												
2	Collecting rocket testing stand literature reviews and descriptions												
3	Preparation of proposal for "Design and Simulation of Experimental Rocket Testing Stand"												
4	Collecting literature reviews ,basic data and recommended simulation software for final project paper												
5	Detail designs of the test stand using AUTODEK												

6	System design of the test stand using MATLAB SIMULINK													
7	Preparation of draft project paper for the test stand (Initial)													
8	3D modeling of the ESSTI model rocket test stand													
9	System simulation of the test stand using MATLAB SIMULINK													
10	Preparation of the second draft project paper the test stand													
11	Project evaluation													
12	Rectifying and solving problems during the process (if any)													
13	Finalizing the final project paper													
14	Final project evaluation													



8. References

1. Available at http://www.spiegl.org/rocket02/SS2S/
2. Available at Richard Nakka. Sts-5000 static test stand for rocket motors. http://www.nakka-rocketry. net/sts 5000f. html Last Accessed: 12 Sept 2019.
3. Available at http://www.spl.ch/old/facilities/Test-Stand/index.html